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Original Article

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Preoperative Narcotic Use, Impaired Ambulation Status, and Increased Intraoperative Blood Loss Are Independent Risk Factors for Complications Following Posterior Cervical Laminectomy and Fusion Surgery

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Objective: This retrospective cohort study seeks to identify risk factors associated with complications following posterior cervical laminectomy and fusion (PCLF) surgery.
Methods: Adults undergoing PCLF from 2012 through 2018 at a single center were identified. Demographic and radiographic data, surgical characteristics, and complication rates were compared. Multivariate logistic regression models identified independent predictors of complications following surgery.
Results: A total of 196 patients met the inclusion criteria and were included in the study. The medical, surgical, and overall complication rates were 10.2%, 23.0%, and 29.1% respectively. Risk factors associated with medical complications in multivariate analysis included impaired ambulation status (odds ratio [OR], 2.27; p = 0.02) and estimated blood loss over 500 mL (OR, 3.67; p = 0.02). Multivariate analysis revealed preoperative narcotic use (OR, 2.43; p = 0.02) and operative time (OR, 1.005; p = 0.03) as risk factors for surgical complication, whereas antidepressant use was a protective factor (OR, 0.21; p = 0.01). Overall complication was associated with preoperative narcotic use (OR, 1.97; p = 0.04) and higher intraoperative blood loss (OR, 1.0007; p = 0.03).
Conclusion: Preoperative narcotic use and estimated blood loss predicted the incidence of complications following PCLF for CSM. Ambulation status was a significant predictor of the development of a medical complication specifically. These results may help surgeons in counseling patients who may be at increased risk of complication following surgery.

Keywords: Posterior cervical fusion, Complication, Risk factor, Narcotics, Cervical spondylotic myelopathy

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is a major cause of disability in the United States.[1] When compared to patients with other chronic debilitating diseases, those with CSM had a high rate of baseline disability and increased socioeconomic burden.[1] It is estimated that 1.6 per 100,000 people have symptomatic CSM requiring surgery, and its incidence continues to rise with the aging patient population.[2,3] The onset of symptoms is usually insidious, with patients experiencing a variety of different symptoms which may include neck pain with or without associated radiculopathy, decreased hand dexterity, gait imbalance, and bowel or bladder incontinence.[4,5] Posterior cervical laminectomy and fusion (PCLF) remain a highly effective treatment strategy for patients with multi-level disease and significant dorsal compression. It may become even more utilized as the aging population demonstrates the increasing severity of cervical spondylosis.[6,8]

Complication rates for procedures that treat CSM are estimated to be about 10.4% overall, and the reported complication rates for PCLF are even greater, ranging from 12.5% to 16.9% in the existing literature.[9-12] Therefore, it is important to identify potential risk factors in order to optimize clinical outcomes. A recent study found that hypoalbuminemia, indicating malnutrition, was a significant risk factor for complication and prolonged length of stay following PCLF surgery.[10] However, few others have examined potential predictors of complications associated with PCLF specifically.[13] Our study seeks to identify potential risk factors for medical and surgical complications following PCLF surgery.

MATERIALS AND METHODS

1. Patient Population

The electronic medical records of consecutive patients who underwent PCLF were reviewed from May 2012 through July 2018 at a single, high-volume academic spine center. Exclusion criteria included non-CSM diagnosis such as vertebral neoplasm or acute vertebral fracture, and patients who had concurrent or staged anterior cervical spine surgery. The perioperative records and imaging were reviewed and analyzed. Clinical records and imaging up to 3 months postoperatively were reviewed to identify adverse events. Medical research was conducted according to the World Medical Association Declaration of Helsinki. This study was approved by our Institutional Committee on Human Research as the Institutional Review Board of record (study #18-24941). Patient consent was not required given that the only record linking the subject and the research would be the informed consent form and the principal risk of the present study is the potential harm resulting from a breach of confidentiality.

2. Data Collection

Demographic variables examined included age, sex, smoking status (current smoker or never/former smoker), insurance (private insurance, Medicare, Medicaid, or uninsured), revision surgery, and American Society of Anesthesiologists (ASA) physical status classification grades. Neurologic risk factors included an ambulation status (independent, assisted, or nonambulatory), primary indication for surgery (radiculopathy or myelopathy), and the presence of any motor deficit. Comorbidities examined included diabetes, coronary artery disease (CAD), psychiatric disorder, chronic renal disease, chronic pulmonary disease, arthritis of a major joint (shoulder, hip, or knee), and osteoporosis. Preoperative medications examined included muscle relaxants, antidepressants, antianxiety medication, and narcotic use. Preoperative medication use was defined as the presence of any active prescription at the time of surgery. Preoperative radiographic data examined included cervical lordosis, T1 slope, cervical sagittal vertical axis, chin-brow vertical angle, proximal junctional angle, distal junctional angle, sacral slope, pelvic incidence, pelvic tilt, lumbar lordosis, and thoracic kyphosis. All radiographic measurements were taken of sagittal plain film X-rays using eUnity software (ver. 6.3.0.1-4; Client Outlook Inc., Waterloo, ON, Canada). Measurements were made by 2 observers using radiographic parameters defined in previous literature.[7,14,15] Interrater reliability, as measured by intraclass correlation, was 0.947 (95% confidence interval [CI], 0.943–0.951). Surgical characteristics examined included number of vertebrae fused, whether fusion crossed the cervicothoracic junction, estimated blood loss (EBL), operative time and whether laminectomy was performed, concurrently or in stages.

The primary outcome measured was the 30-day complication rate, defined as the proportion of patients who experienced an adverse event. This was refined further into 3 categories: medical complications, surgical complications, and overall complication. Medical complications included urinary tract infection (UTI), anemia, thrombotic events, arrhythmia, cardiac arrest, pneumonia, sepsis, and death. Surgical complications included dysphagia, durotomy, surgical site infection, seroma, new neurologic deficit, implant malposition, and surgical revision within 30 days. Overall complication was defined as the presence of a medical complication, a surgical complication, or both.

Table 1. Patient demographics

Demographic	Value
Age (yr)	63 ± 11.37
Female sex	90 (45.9)
Current smoker	17 (8.7)
Insurance	
Medicare	110 (56.1)
Medicaid	24 (12.2)
Private Insurance	90 (45.9)
Uninsured	2 (1.0)
Revision surgery	20 (10.2)
ASA grade III+	90 (45.9)
Neurologic	
Ambulatory status	
Independent	135 (68.9)
Assisted	36 (18.4)
Nonambulatory	25 (12.7)
Indication for surgery	
Radiculopathy	28 (14.3)
Myelopathy	155 (79.1)
Cervical instability	12 (6.1)
Motor deficit	132 (67.3)
Comorbidities	
Diabetes	33 (16.8)
CAD	14 (7.1)
Psychiatric disorder	69 (35.2)
Chronic renal disease	12 (6.1)
Chronic pulmonary disease	21 (10.7)
Arthritis	32 (16.3)
Osteoporosis	20 (10.2)
Preoperative medications	
Muscle relaxants	39 (19.9)
Antidepressant	37 (18.9)
Antianxiety	34 (17.3)
Narcotics	101 (51.5)
Preoperative radiographic parameters	
Cervical lordosis (°)	8.53 ± 14.61
T1 slope (°)	29.37 ± 10.86
cSVA (mm)	33.82 ± 17.61
Chin-brow vertical angle (°)	1.94 ± 8.79
Proximal junctional angle (°)	-34.25 ± 18.53
Distal junctional angle (°)	0.09 ± 6.44
Sacral slope (°)	38.12 ± 11.84
Pelvic incidence (°)	58.89 ± 14.46
Pelvic tilt (°)	21.70 ± 11.98
Lumbar lordosis (°)	48.792 ± 15.82
Thoracic kyphosis (°)	31.31 ± 11.64
SVA (mm)	37.73 ± 40.92
Procedure	
Laminectomy performed	184 (93.9)
No. of vertebrae fused	4.2 ± 1.9
EBL over 500 mL	28 (14.3)
Operative time (min)	221.4 ± 97.7

Values are presented as mean ± standard deviation or number (%).
ASA, American Society of Anesthesiologists physical status classification; CAD, coronary artery disease; cSVA, cervical sagittal vertical axis; SVA, sagittal vertical axis; EBL, estimated blood loss.

3. Statistical Analysis

Continuous risk factors are presented as means and standard deviations. Categorical risk factors are presented as the number of cases and percentages. Univariate analysis was used to identify predictors of postoperative complication. Chi-square, Fisher exact, and Student t-tests were performed and OR, 95% CI, and p-values were generated. Variables significant at $p = 0.20$ were included in multivariate analysis. Patients with missing data for any included variable were omitted. A stepwise multivariate logistic regression was performed to examine each variable's relative contribution and calculate the adjusted OR, CI, and p-values. Statistical analyses were performed using custom scripts (RStudio software ver. 1.1.463; RStudio, Boston, MA, USA) running on Windows 10 Pro.

RESULTS

1. Demographics

A total of 291 patients were initially identified from the electronic database. There were 81 patients excluded due to non-CSM diagnosis such as vertebral neoplasm or acute vertebral fracture, or other diagnoses unrelated to CSM, and another 14 patients were excluded due to concurrent or staged anterior cervical surgery. After applying the exclusion criteria, the perioperative records and imaging studies of the remaining 196 patients were reviewed and analyzed. Clinical records and imaging up to 3 months postoperatively were reviewed to identify adverse events.

The demographics of this cohort are provided in Table 1. The

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mean age was 63 ± 11.37 years, there were 90 female patients (45.9%) and 17 patients (8.7%) were smokers. There were 20 revision cases (10.2%), and 90 patients (45.9%) had ASA physical status classification grade of III or greater. Most patients ambulated independently (n = 135, 68.9%), but many also had one or more motor deficit (n = 132, 67.3%). The most common comorbidities were psychiatric disorders (n = 69, 35.2%), diabetes (n = 33, 16.8%), and arthritis (n = 32, 16.3%). Approximately half of patients (n = 101, 51.5%) reported preoperative narcotic use. Approximately 20% of patients had preoperative use of muscle relaxants (n = 39, 19.9%), antidepressants (n = 37, 18.9%), and antianxiety medications (n = 34, 17.4%). Preoperative imaging showed an average cervical lordosis of 8.5° ± 14.6°, a T1 slope of 29.3° ± 10.9°, and a cervical sagittal vertebral axis (cSVA) of 33.8 ± 17.6 mm. The average number of fused levels was 4.2 ± 1.9, with a mean operative time of 221.4 ± 97.7 minutes.

2. Postoperative Complications

The 30-day postoperative complication rates are shown in Table 2. Medical complications occurred in 20 patients (10.2%), the most common of which were acute blood loss anemia (n = 7, 3.6%), UTIs (n = 5, 2.6%), and cardiac arrhythmias (n = 4, 2.0%). Major medical complications occurred in 6 patients (3.1%), with 2 cases of pneumonia, one cardiac arrest, and one death within 30 days of surgery. Surgical complications occurred in 45 patients (23.0%). Of these, the most common complications included a new neurologic deficit following surgery (n = 16, 8.2%), durotomy (n = 11, 5.6%), and wound infections (n = 7, 3.6%). Three patients (1.5%) had malpositioned implants or grafts and required revision surgery within 30 days. Overall, 57 patients (29.1%) experienced at least one medical or surgical complication.

3. Univariate Analysis

Univariate analysis of risk factors for postoperative complications is presented in Table 3. Significant predictors for medical complication included EBL over 500 mL (OR, 3.97; p = 0.01), thoracic kyphosis (OR, 1.07; p = 0.01), cSVA (OR, 1.03; p = 0.04), and operative time (OR, 1.007; p = 0.004). ASA physical status classification grade was not a significant predictor at the univariate level (OR, 2.25; p = 0.09). There were no significant risk factors for surgical complication on univariate analysis. Overall complication incidence was predicted by EBL over 500 mL (OR, 2.91; p = 0.01) operative time (OR, 1.004; p = 0.03).

Table 2. Incidence of 30-day complications

Complication	No. (%)
Medical complications	
Minor	18 (9.2)
Urinary tract infection	5 (2.6)
Anemia	7 (3.6)
Excessive blood loss (> 3 L)	1 (0.5)
Pneumothorax	0 (0)
Deep vein thrombosis	3 (1.5)
Arrhythmia*	4 (2.0)
Major	6 (3.1)
Myocardial infarction	0 (0)
Cardiac arrest	1 (0.5)
Pneumonia	2 (1.0)
Pulmonary embolism	1 (0.5)
Cerebrovascular event	1 (0.5)
Sepsis	1 (0.5)
Death	1 (0.5)
Any medical complication	20 (10.2)
Surgical complications	
Minor	39 (19.9)
Dysphagia	5 (2.6)
Vocal cord paralysis	1 (0.5)
Pain control	4 (2.0)
Durotomy	11 (5.6)
Superficial wound infection	4 (2.0)
Cerebrospinal fluid leak	0 (0)
Seroma	5 (2.6)
Wound dehiscence	0 (0)
New neurologic deficit (weakness, palsy, numbness)	16 (8.2)
Major	8 (3.8)
Deep wound infection	3 (1.5)
Implant/graft malposition	3 (1.5)
Wrong level surgery	0 (0)
Pseudomeningocele	0 (0)
Revision required within 30 days	3 (1.5)
Any surgical complication	45 (23.0)
Any medical or surgical complication	57 (29.1)

*Arrhythmia includes atrial fibrillation, premature atrial contraction, premature ventricular contraction, and sinus tachycardia.

4. Multivariate Analysis

Each multivariate regression model initially included all variables significant at p < 0.20 on univariate analysis and was iterated until only variables significant at p < 0.05 remained. Poten-

Table 3. Univariate analysis of predictors of 30-day complications

Variable	Medical complication	OR (95% CI)	p-value	Surgical complication	OR (95% CI)	p-value	Any complication	OR (95% CI)	p-value
Demographics									
Age (yr)									
<65	9 (8.4)	Ref	Ref	24 (22.4)	Ref	Ref	29 (2.1)	Ref	Ref
≥65	11 (12.4)	1.02 (0.98–1.06)	0.43	21 (23.6)	1.01 (0.98–1.04)	0.61	28 (31.5)	1.01 (0.99–1.04)	0.38
Sex									
Male	14 (13.2)	Ref	Ref	25 (23.6)	Ref	Ref	34 (32.1)	Ref	Ref
Female	6 (6.7)	0.47 (0.16–1.23)	0.14	20 (20.2)	0.93 (0.47–1.80)	0.43	23 (25.6)	0.73 (0.39–1.35)	0.32
Smoking status									
Never or former smoker	20 (11.5)	Ref	Ref	35 (20.1)	Ref	Ref	47 (27.0)	Ref	Ref
Current smoker	0 (0)	N/A	N/A	6 (35.3)	2.17 (0.71–6.11)	0.14	6 (35.3)	1.47 (0.48–4.10)	0.54
Medicare	13 (11.8)	1.51 (0.59–4.19)	0.40	28 (25.5)	1.39 (0.71–2.78)	0.62	34 (30.9)	1.23 (0.66–2.31)	0.52
Medicaid	2 (8.3)	0.78 (0.12–2.95)	0.75	5 (20.8)	0.87 (0.27–2.32)	0.55	7 (29.2)	1.00 (0.36–2.48)	0.99
Private insurance	9 (10.0)	0.96 (0.37–2.43)	0.93	19 (21.1)	0.82 (0.42–1.61)	0.65	25 (27.8)	0.89 (0.48–1.65)	0.71
Uninsured	0 (0)	0 (0–NaN)	1	1 (50.0)	3.41 (0.13–87.39)	0.36	1 (50.0)	2.46 (0.10–63.04)	0.53
Revision surgery									
No	17 (9.7)	Ref	Ref	39 (22.3)	Ref	Ref	51 (29.1)	Ref	Ref
Yes	3 (15.0)	1.64 (0.36–5.54)	0.46	6 (30.0)	1.49 (0.50–4.00)	0.69	6 (30.0)	1.04 (0.35–2.75)	0.94
ASA grade									
<III	7 (6.6)	Ref	Ref	23 (21.7)	Ref	Ref	28 (26.4)	Ref	Ref
III+	13 (14.4)	2.25 (0.90–6.19)	0.09	22 (24.4)	1.07 (0.56–2.06)	1	29 (32.2)	1.21 (0.67–2.23)	0.53
Neurologic									
Ambulatory status		1.65 (0.91–2.90)	0.09		1.07 (0.66–1.68)	0.73		1.21 (0.79–1.84)	0.38
Independent	10 (7.4)			29 (21.5)			36 (26.7)		
Assisted	6 (16.7)			11 (30.6)			13 (36.1)		
Nonambulatory	4 (16.0)			5 (20.0)			8 (32.0)		
Indication for surgery		2.21 (0.78–6.58)	0.15		1.17 (0.57–2.46)	0.96		1.15 (0.59–2.30)	0.68
Radiculopathy	0 (0)			6 (21.4)			6 (21.4)		
Myelopathy	16 (10.3)			36 (23.2)			46 (29.7)		
Motor deficit	14 (10.6)	1.04 (0.40–2.94)	0.94	33 (25.0)	1.57 (0.75–3.48)	0.33	40 (30.3)	1.25 (0.64–2.49)	0.52
Comorbidities									
Diabetes	6 (18.2)	2.33 (0.77–6.39)	0.11	8 (24.2)	1.07 (0.42–2.49)	0.69	11 (33.3)	1.25 (0.55–2.74)	0.58
Coronary artery disease	3 (21.4)	2.61 (0.55–9.39)	0.17	5 (35.7)	1.94 (0.57–5.96)	0.19	6 (42.9)	1.90 (0.60–5.73)	0.26

(*Continued to the next page*)

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Table 3. Continued

Variable	Medical complication	OR (95% CI)	p-value	Surgical complication	OR (95% CI)	p-value	Any complication	OR (95% CI)	p-value
Psychiatric disorder	10 (14.5)	1.98 (0.77–5.09)	0.15	14 (20.3)	0.79 (0.38–1.58)	0.52	22 (31.9)	1.23 (0.64–2.32)	0.52
Chronic renal disease	1 (8.3)	0.78 (0.04–4.36)	0.82	4 (33.3)	1.72 (0.44–5.75)	0.32	4 (33.3)	1.22 (0.31–4.04)	0.76
Chronic pulmonary disease	0 (0)	0 (0–NaN)	0.08	4 (33.3)	0.52 (0.12–1.63)	0.39	4 (33.3)	0.37 (0.08–1.14)	0.12
Arthritis	2 (6.3)	1.81 (0.55–5.14)	0.28	6 (18.8)	0.73 (0.26–1.79)	0.97	10 (31.3)	1.11 (0.47–2.48)	0.80
Osteoporosis	3 (15.0)	2.47 (0.65–7.75)	0.14	6 (30.0)	1.48 (0.50–3.97)	0.13	8 (40.0)	1.70 (0.63–4.37)	0.28
Preoperative medications									
Muscle relaxants	3 (7.7)	0.67 (0.15–2.14)	0.54	7 (17.9)	0.69 (0.26–1.62)	0.43	9 (23.1)	0.69 (0.29–1.50)	0.36
Antidepressant	6 (16.7)	1.96 (0.65–5.32)	0.20	4 (10.8)	0.35 (0.10–0.95)	0.06	10 (27.0)	0.89 (0.38–1.93)	0.77
Antianxiety	7 (21.2)	1.19 (0.32–3.53)	0.77	9 (26.5)	1.28 (0.52–2.90)	0.72	11 (32.4)	1.21 (0.53–2.64)	0.64
Narcotics	15 (15.0)	1.47 (0.58–3.91)	0.43	28 (27.7)	1.76 (0.90–3.53)	0.10	35 (34.7)	1.76 (0.94–3.33)	0.07
Preoperative radiographic parameters									
Cervical lordosis		1.01 (0.98–1.05)	0.59		1.00 (0.97–1.02)	0.91		1.00 (0.98–1.02)	0.97
T1 slope		1.01 (0.98–1.04)	0.26		1.01 (0.98–1.04)	0.48		1.00 (0.98–1.04)	0.67
cSVA		1.03 (1.00–1.06)	0.04		1.01 (0.99–1.03)	0.17		1.02 (0.99–1.04)	0.11
Chin-brow vertical angle		1.06 (0.94–1.19)	0.30		0.98 (0.90–1.06)	0.67		1.01 (0.93–1.08)	0.89
Proximal junctional angle		1.00 (0.95–1.05)	0.98		0.99 (0.96–1.01)	0.43		0.99 (0.97–1.02)	0.58
Distal junctional angle		1.04 (0.94–1.16)	0.50		1.02 (0.95–1.10)	0.63		1.00 (0.95–1.07)	0.90
Sacral slope		1.04 (0.98–1.09)	0.18		1.00 (0.96–1.04)	0.97		1.02 (0.99–1.05)	0.38
Pelvic incidence		1.01 (0.97–1.06)	0.56		1.01 (0.98–1.04)	0.64		1.01 (0.98–1.04)	0.40
Pelvic tilt		0.97 (0.92–1.03)	0.40		1.00 (0.97–1.04)	0.84		1.00 (0.96–1.03)	0.80
Lumbar lordosis		1.03 (0.99–1.07)	0.17		1.01 (0.98–1.04)	0.51		1.01 (0.99–1.04)	0.34
Thoracic kyphosis		1.07 (1.02–1.14)	0.01		1.03 (0.99–1.07)	0.14		1.03 (0.99–1.06)	0.10
SVA		0.99 (0.98–1.01)	0.34		1.00 (0.99–1.01)	0.99		1.00 (0.99–1.01)	0.89
Procedure									
Laminectomy performed	20 (11.0)	0.54 (0.13–3.71)	0.45	43 (23.4)	1.52 (0.38–10.17)	0.59	54 (29.3)	1.25 (0.36–5.78)	0.74
Length of fusion		1.19 (0.94–1.51)	0.14		1.03 (0.86–1.22)	0.78		1.05 (0.90–1.23)	0.54
Estimated blood loss (per mL)		1.001 (1.00–1.002)	0.004		1.00 (1.00–1.00)	0.22		1.0005 (1.00003–1.001)	0.11
≤500 mL	13 (7.7)	Ref	Ref	35 (20.8)	Ref	Ref	43 (25.6)	Ref	Ref
>500 mL	7 (25.0)	3.97 (1.36–10.91)	0.01	10 (35.7)	2.11 (0.87–0.91)	0.09	15 (50.0)	2.91 (1.28–6.64)	0.01
Operative time (min)		1.007 (1.003–1.01)	0.004		1.003 (1.00–1.006)	0.10		1.004 (1.00–1.01)	0.03

Values presented as number (%) unless otherwise indicated.
OR, odds ratio; CI, confidence interval; ASA, American Society of Anesthesiologists physical status classification; CAD, coronary artery disease; cSVA, cervical sagittal vertical axis; SVA, sagittal vertical axis; N/A, not applicable; NaN, not a number.

Table 4. Multivariate logistic regression of risk factors for 30-day medical complication

Risk factor	Odds ratio	95% CI		p-value
Impaired ambulation	2.27	1.14	4.50	0.02*
Thoracic kyphosis (°)	1.08	1.03	1.14	0.004*
EBL over 500 mL	3.67	1.15	11.27	0.02*

CI, confidence interval; EBL, estimated blood loss.
*p < 0.05.

Table 5. Multivariate logistic regression of risk factors for 30-day surgical complication

Risk factor	Odds ratio	95% CI		p-value
Antidepressant use	0.21	0.05	0.64	0.01*
Narcotic use	2.43	1.17	5.18	0.02*
Operative time (min)	1.005	1.00	1.01	0.03*

CI, confidence interval.
*p < 0.05.

tial risk factors for medical complications included ambulation status, indication for surgery, several comorbidities (diabetes, CAD, psychiatric disorders, osteoporosis), preoperative antidepressant use, ASA score, cSVA, lumbar lordosis, thoracic kyphosis, length of fusion, EBL, and operative time (Table 4). Of these, ambulation status (OR, 2.27; p = 0.02), EBL over 500 mL (OR, 3.67; p = 0.02), and thoracic kyphosis (OR, 1.08; p = 0.004) emerged as significant predictors. Impaired ambulation was significantly associated with increased incidence of postoperative UTI (p = 0.004) (Supplementary Table 1) and EBL greater than 500 mL was associated with acute anemia (p = 0.006, Supplementary Table 2).

Variables included in the surgical complication model included smoking, CAD, osteoporosis, preoperative antidepressant and narcotic use, cSVA, thoracic kyphosis, EBL, and operative time. Of these, preoperative narcotic use (OR, 2.43; p = 0.02) and operative time (OR, 1.005; p = 0.03) were risk factors for surgical complication, whereas preoperative antidepressant use (OR, 0.21; p = 0.01) was a protective factor (Table 5). More specifically, operative time was significantly associated with increased incidence of dysphagia (p = 0.01) (Supplementary Table 3). Independent risk factors for overall postoperative complication were narcotic use (OR, 1.97; p = 0.04) and EBL (OR, 1.0007; p = 0.03) (Table 6), the latter of which was associated with new postoperative neurologic deficit (p = 0.02) (Supplementary Table 2).

Table 6. Multivariate logistic regression of risk factors for 30-day overall complication

Risk factor	Odds ratio	95% CI		p-value
Narcotic use	1.97	1.03	3.82	0.04*
EBL over 500 mL	1.0007	1.00002	1.002	0.03*

CI, confidence interval; EBL, estimated blood loss.
*p < 0.05.

DISCUSSION

The present study utilized a retrospective chart review to identify pre- and intraoperative predictors of complication following PCLF surgery. We found statistically significant associations between medical complications and impaired preoperative ambulation status, and increased EBL, and increased preoperative thoracic kyphosis. Surgical complication was associated with preoperative narcotic use and increased operative time. Finally, patients with preoperative narcotic use and intraoperative blood loss > 500 mL had statistically significant increased odds of overall complication following PCLF surgery.

The overall complication rate of 29.1% in this study is higher than those previously reported in the literature.[9,11,12,16,17] This is mainly due to the expanded definition of "complication" used in our study compared to that of the NSQIP database, which is utilized in many previous studies.[18] We included minor medical complications such as UTI, postoperative anemia, transient cardiac arrhythmia, and other surgical complications inherent to spinal surgery such as incidental durotomy and transient dysphagia were also included. In addition, new neurological deficits in this study included postoperative numbness and transient worsening weakness, which usually improved overtime. Excluding these minor complications from the analysis, the overall complication rate would decrease to 9.8%, which would be consistent with previously reported complication rates in the literature.

Ambulation status was found to be an important predictor for medical complications, in which patients with impaired preoperative ambulation status had 2.27 times greater odds of medical complication compared to those who ambulated independently (p = 0.02) and was associated with a greater incidence of postoperative UTIs specifically (p = 0.004). This finding is supported by a previous study, which had found that preoperative walking disabilities were associated with increased risk of venous thromboembolic events following spine surgery.[19] The impaired ambulation status can be a consequence of CSM, but

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it may also be an indicator for patient frailty.[16,20] The observed relationship between ambulatory status and UTIs may be explained by several mechanisms. Patients with significant CSM causing impaired ambulation are often observed to have neurogenic bladder symptoms associated with their condition as well. Though the goal of PCF surgery is to relieve cord compression and, therefore, bladder dysfunction, in some cases incomplete decompression can lead to continuation of preoperative symptoms. Alternatively, prior work has shown that poor mobility is itself associated with UTIs by allowing patients to independently void and decrease periods of urinary stasis, which is a predisposing factor to infection.[21] Furthermore, patients with impaired mobility are more likely to have urinary catheter for longer periods of time, which may also increase the risk of UTI. Thus, loss of independent ambulation may serve as a predictor of postoperative complications and poor outcomes, establishing its importance as a potentially modifiable risk factor. "Prehabilitation" programs, which seek to improve surgical outcomes by providing preoperative physical and nutritional therapy to frail patients, may be an apt intervention to address the increased risk conferred by loss of mobility.

EBL is a well-established risk factor for perioperative complication in spine surgery.[4,22,23] Our study supports this association, finding that EBL >500 mL is associated with more than threefold greater odds of medical complication ($p=0.02$). Increased EBL was also associated with a small, but statistically significant increase in the odds of overall complication ($p=0.03$). Blood loss may lead to adverse events through a variety of pathways, from fluid shifts affecting cardiac, pulmonary, and renal status to impairment of the immune system leading to postoperative infections.[24] The association found in this study between larger blood loss and acute anemia is evident, however the observed relationship with new neurologic deficits after surgery is less obvious. For some patients, EBL may serve as a proxy for invasiveness and complexity of surgery, which could predispose patients to nerve injury and associated deficits. This result suggests that minimizing EBL may help to decrease postoperative complications.[25]

Preoperative narcotic use was identified as an important predictor of postoperative complications in our study. One previous study found that narcotic use was not associated with complications up to 90 days after surgery.[26] However, a recent retrospective database analysis by Jain et al.[27] reported that preoperative opioid use was associated with an eightfold increase in odds of complication following posterior lumbar fusion surgery. The present study lends support to the latter finding, which may be explained through several biological mechanisms. Activation of cutaneous opioid receptors has been shown to interfere with angiogenesis, delay and reduce neutrophil and macrophage recruitment to the surgical site, and alter neuropeptide signaling that is essential for wound healing.[28-30] The difference in effect size (OR of 2.43 for surgical complication and 1.97 for overall complication, versus 8.08 in previous work) may be attributed to a shorter follow-up time capturing fewer complications in narcotic-using patients in our study (30 days versus 90 days). This likely explains the lack of significant associations with specific postoperative complications as well. For example, the incidence of surgical site infection was greater in the narcotic use group and, though this finding is supported by our mechanistic understanding of wound healing, it did not reach significance (Supplementary Table 4).

Antidepressant use was the only protective factor for surgical complication identified. Depression and anxiety have well-documented associations with poor outcomes after spine surgery, having been shown to lead to increased Nurick scores and rates of delirium.[31,32] Prior research has revealed that treatment of these disorders with antidepressants attenuates this increase in complications.[33] This finding highlights the importance of preoperative treatment of psychiatric conditions.

Several other risk factors previously linked to postoperative complication were not found to be independent predictors in this study. While diabetes is often identified as a modifiable risk factor with a significant role in the incidence of complication, it did not emerge as a significant predictor in the univariate or multivariate analysis here.[34-36] Likewise, many studies cite body mass index (BMI) as an independent predictor of surgical site infection, though recent work has repudiated this finding.[37-40] In this study, BMI was included in the multivariate models for medical and overall complication, but its independent contribution was found to be insignificant ($p=0.33$ and $p=0.98$, respectively).

The present study has several limitations. As a retrospective study relying on chart review for data collection, it is subject to errors in the medical charts (i.e., missed diagnoses) and to the interpretation of the information therein. Underestimation of complications is another concern, as patients may seek care elsewhere within 30 days of surgery. Finally, our definition of preoperative opioid use did not include the actual dose information and is thus an incomplete metric of the extent of patients' actual opioid use.

CONCLUSION

Preoperative narcotic use and impaired ambulation were identified as modifiable risk factors for complications after PCLF. Preoperative "Opioid-weaning" and "Prehabilitation" programs may help to reduce postoperative complications. Increased EBL and operative time also increased the odds of short-term complications after surgery. Spine surgeons should keep these results in mind when counseling patients regarding risks associated with PCLF.

CONFLICT OF INTEREST

The authors have nothing to disclose.

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SUPPLEMENTARY MATERIALS

Supplementary Tables 1-4 can be found via https://doi.org/10.14245/ns.1938198.099.

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Supplementary Table 1. Medical complications associated with impaired ambulation

Complication	Independent ambulation	Impaired ambulation	p-value
Anemia	5 (3.7)	2 (3.3)	>0.99
UTI	0 (0)	5 (8.2)	0.004*
Arrhythmia	2 (1.5)	2 (3.3)	0.78
DVT	1 (0.7)	2 (3.3)	0.47
PE	0 (0)	1 (1.6)	0.68
Pneumonia	2 (1.5)	0 (0)	0.85
CVA	0 (0)	1 (1.6)	0.68
Cardiac arrest	0 (0)	1 (1.6)	0.68
Death	0 (0)	1 (1.6)	0.68

Values are presented as number (%).
UTI, urinary tract infection; DVT, deep vein thrombosis; PE, pulmonary embolism; CVA, cerebrovascular accident.
*p<0.05.

Supplementary Table 2. Medical and overall complications associated with estimated blood loss

Complication	≤500 mL	>500 mL	p-value
Anemia	3 (1.8)	4 (14.3)	0.006*
UTI	4 (2.4)	1 (3.6)	>0.99
Arrhythmia	3 (1.8)	1 (3.6)	>0.99
DVT	1 (0.6)	2 (7.1)	0.07
PE	1 (0.6)	0 (0)	>0.99
Pneumonia	2 (1.2)	0 (0)	>0.99
Sepsis	1 (0.6)	0 (0)	>0.99
CVA	0 (0)	1 (3.6)	0.31
Cardiac arrest	0 (0)	1 (3.6)	0.31
Death	0 (0)	1 (3.6)	0.31
Surgical site infection	7 (4.2)	0 (0)	0.58
Dysphagia	2 (1.2)	3 (10.7)	0.02
Vocal paralysis	0 (0)	1 (3.6)	0.31
New neurologic deficit	10 (6.0)	6 (21.4)	0.02*
Durotomy	10 (6.0)	1 (3.6)	0.95
Seroma	4 (2.4)	0 (0)	0.92
Pain control difficulty	4 (2.4)	0 (0)	0.92
Implant malposition	1 (0.6)	2 (7.1)	0.07
Revision within 30 days	1 (0.6)	2 (7.1)	0.07

Values are presented as number (%).
UTI, urinary tract infection; DVT, deep vein thrombosis; PE, pulmonary embolism; CVA, cerebrovascular accident.
*p<0.05.

Supplementary Table 3. Surgical complications associated with operative time

Complication	>240 min	≤240 min	p-value
Surgical site infection	4 (3.0)	3 (4.9)	0.06
Dysphagia	2 (1.5)	3 (4.9)	0.01*
Vocal paralysis	0 (0)	1 (1.6)	>0.99
New neurologic deficit	9 (6.7)	7 (11.5)	0.28
Durotomy	9 (6.7)	2 (3.3)	0.42
Seroma	4 (3.0)	0 (0)	0.34
Pain control difficulty	4 (3.0)	0 (0)	0.34
Implant malposition	1 (0.7)	2 (3.3)	0.07
Revision within 30 days	1 (0.7)	2 (3.3)	0.07

Values are presented as number (%).
*p<0.05.

Supplementary Table 4. Surgical and overall complications associated with preoperative narcotic use

Complication	No	Yes	p-value
Anemia	4 (4.2)	3 (3.0)	0.92
UTI	1 (1.1)	4 (4.0)	0.41
Arrhythmia	3 (3.2)	1 (1.0)	0.56
DVT	2 (2.1)	1 (1.0)	0.95
PE	1 (1.1)	0 (0)	0.97
Pneumonia	1 (1.1)	1 (1.0)	>0.99
Sepsis	1 (1.1)	0 (0)	0.97
CVA	0 (0)	1 (1.0)	>0.99
Cardiac arrest	0 (0)	1 (1.0)	>0.99
Death	0 (0)	1 (1.0)	>0.99
Surgical site infection	2 (2.1)	5 (5.0)	0.50
Dysphagia	2 (2.1)	3 (3.0)	>0.99
Vocal paralysis	1 (1.1)	0 (0)	0.97
New neurologic deficit	8 (8.4)	8 (7.9)	>0.99
Durotomy	3 (3.2)	8 (7.9)	0.26
Seroma	4 (4.2)	0 (0)	0.05
Pain control difficulty	1 (1.1)	3 (3.0)	0.66
Implant malposition	1 (1.1)	2 (2.0)	>0.99
Revision within 30 days	1 (1.1)	2 (2.0)	>0.99

Values are presented as number (%).
UTI, urinary tract infection; DVT, deep vein thrombosis; PE, pulmonary embolism; CVA, cerebrovascular accident.
*p<0.05.

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